
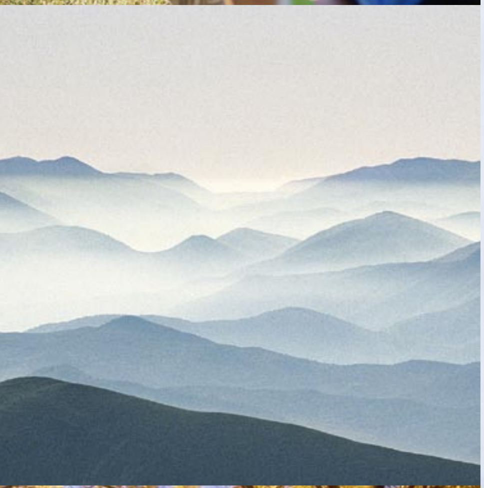

Acid Rain Program

2003 Progress Report

SEPTEMBER 2004

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

CLEAN AIR MARKET PROGRAMS

The Acid Rain Program Progress Report is published annually by EPA to update the public on compliance with the Acid Rain Program, the status of implementation, and progress toward achieving environmental goals. The Acid Rain Program 2003 Progress Report updates data reported in previous years, specifically:

- SO_2 emissions, allowance market information, and program compliance
- NO_X emissions and program compliance
- Status and trends in acid deposition, air quality, and ecological effects

Detailed unit-level emissions data are available on EPA's Clean Air Markets website. For more information on the Acid Rain Program, including additional information on SO_2 and NO_X emissions, acid deposition monitoring, and the environmental effects of acid deposition, please visit EPA's Clean Air Markets website at www.epa.gov/airmarkets.

EPA Acid Rain Program
2003 Progress Report
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Clean Air Markets Division
Office of Air and Radiation
U.S. Environmental Protection Agency

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Summary

Congress created the Acid Rain Program in Title IV of the 1990 Clean Air Act Amendments. The Acid Rain Program has the goals of lowering the electric power industry's annual emissions of:

- Sulfur dioxide (SO_2) to half of 1980 levels, capping them at 8.95 million tons starting in 2010, and
- Nitrogen oxide (NO_X) to 2 million tons lower than the forecasted level for 2000, reducing annual emissions to a level of 6.1 million tons in 2000.

In 2003, Acid Rain Program emission controls on the electric power industry resulted in:

- SO_2 emissions of 10.6 million tons, a reduction of 38 percent from 1980 levels. Emissions were 4 percent higher in 2003 than in 2002. This small increase resulted from increased production of electricity by coal-fired and oil-fired units that emit much more SO_2 than natural gas units that generated less power in 2003. The main cause of this was the substantial increase in natural gas prices. Large, early SO_2 reductions that were very beneficial at the program's outset enabled banked allowances to be available to cover these emissions.
- NO_X emissions of 4.2 million tons, which were close to 4 million tons less than the emissions forecasted for 2000. Other regulations, such as the NO_X Budget Program in the Northeast, also contributed to this reduction in emissions.

As in years past, the electric power industry achieved nearly 100 percent compliance with Acid Rain Program requirements — only 1 unit had emissions exceeding the SO_2 allowances that it held and no units were out of compliance with the NO_X program. This exceptionally high level of compliance was, in part, achieved as a result of the Acid Rain Program's continued provision of accurate and complete SO_2 and NO_X emissions data. This process was augmented by a substantial auditing effort and accountability through rigorous, yet streamlined, reporting systems.

SO_2 and NO_X are the key pollutants in the formation of acid rain. These pollutants also contribute to the formation of fine particles (sulfates and nitrates) that are associated with significant health effects and regional haze. Additionally, NO_X combines with volatile organic compounds (VOCs) to form ozone (smog), and nitrates that are transported and deposited at environmentally detrimental levels in parts of the country. The United States (U.S.) electric power industry accounts for approximately 67 percent of total annual SO_2 emissions and 22 percent of total annual NO_X emissions.

Since the Acid Rain Program began in 1995, the lower SO_2 and NO_X emissions levels from the power sector have contributed to significant air quality and environmental improvements that EPA's Clean Air Status and Trends Network (CASTNET) and other long-term environmental monitoring networks are reporting.

Over the last decade:

- Ambient SO_2 and sulfate levels are down more than 40 percent and 30 percent, respectively, in the eastern U.S.
- Wet sulfate deposition, which acidifies sensitive lakes, streams and forest soils, has decreased 39 percent in the northeastern U.S. and 17 percent in the southeastern U.S.
- Some modest reductions in inorganic nitrogen deposition and wet nitrate concentrations have occurred in the Northeast and Mid-Atlantic regions, but other areas have not shown much improvement.
- Signs of recovery in acidified lakes and streams are evident in the Adirondacks, the northern Appalachian Plateau, and the upper Midwest. These signs include lower concentrations of sulfates, nitrates, and improvements in acid neutralizing capacity.

The Acid Rain Program has produced remarkable and demonstrable results. It has reduced SO_2 emissions faster and at far lower costs than anticipated, yielding wide-ranging health and environmental improvements. In fact, during 2003, the Office of Management and Budget found the program accounted for the largest quantified human health benefits — over $70 billion annually — of any federal regulatory program implemented in the last 10 years, with annual benefits exceeding costs by more than 40:1.

Origins of the Acid Rain Program

Acid deposition, more commonly known as acid rain, occurs when emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_X) react in the atmosphere (with water, oxygen, and oxidants) to form various acidic compounds. Prevailing winds transport the acidic compounds hundreds of miles, often across state and national borders, where they may impair air quality and damage public health, acidify lakes and streams, harm sensitive forest and coastal ecosystems, degrade visibility, and accelerate the decay of building materials.

The Acid Rain Program, established under Title IV of the 1990 Clean Air Act Amendments, requires major reductions of SO_2 and NO_X emissions. The SO_2 program sets a permanent cap on the total amount of SO_2 that may be emitted by electric power plants in the contiguous U.S. at about one-half of the amount of SO_2 these sources emitted in 1980. Using a market-based cap and trade mechanism allows flexibility for individual combustion units to select their own methods of compliance. One allowance provides a regulated unit limited authorization to emit one ton of SO_2. Provisions of the 1990 Clean Air Act outline the allocation of allowances to regulated units based on historic fuel consumption and specific emission rates prior to the start of the program. For any year, the number of allowances totals the SO_2 emissions cap.

The program uses a more traditional approach to NO_X emission limitations for certain coal-fired electric utility boilers, with the objective of achieving a 2 million ton reduction from projected NO_X emission levels that would have been emitted in 2000 without implementation of Title IV.

The Acid Rain Program is comprised of two phases for SO_2 and NO_X. Phase I applied primarily to the largest coal-fired electric generation sources from 1995 through 1999 for SO_2 and from 1996 through 1999 for NO_X. Phase II for both pollutants began in 2000. For SO_2, it applies to thousands of combustion units generating electricity nationwide; for NO_X it generally applies to affected units that burned coal during 1990-1995.

SO_2 Emission Reductions

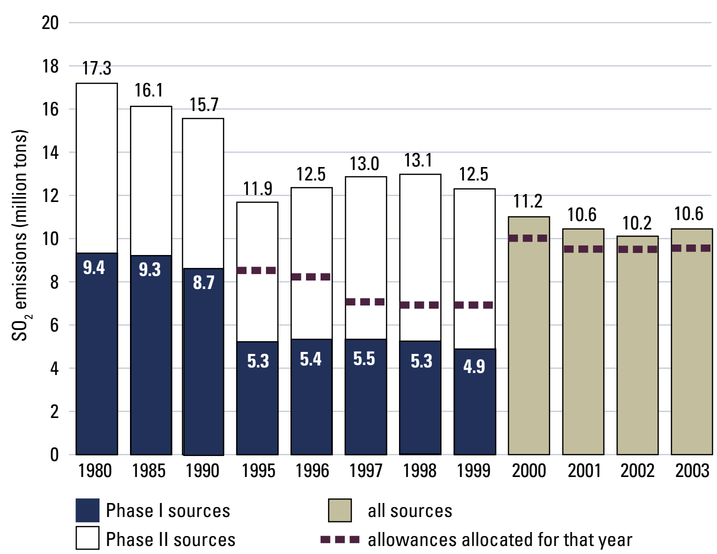
Electric power generation is by far the largest single source of SO_2 emissions in the U.S., accounting for approximately 67 percent of total SO_2 emissions nationwide in 2002.[1] In 2003, 3,497 units were subject to the SO_2 provisions of the Acid Rain Program. That year, 10.6 million tons of SO_2 were emitted, an increase of 4 percent from 2002. To date, Acid Rain Program sources posted a total annual reduction in SO_2 emissions of approximately 38 percent compared to 1980 levels (32 percent compared to 1990 levels). Figure 1 shows the trend in SO_2 emissions since 1980 for all Title IV affected sources.

For 2003, a total of 9.5 million allowances were allocated. Adding these allowances to the 8.6 million unused allowances carried over (or banked) from prior years, a total of 18.2 million allowances were available for use in 2003. Sources emitted 10.6 million tons of SO_2 in 2003, 1.1 million tons more than the allowances granted in the year but far less than the total allowable level.

FIGURE 1

SO_2 Emissions under the Acid Rain Program

Source: EPA

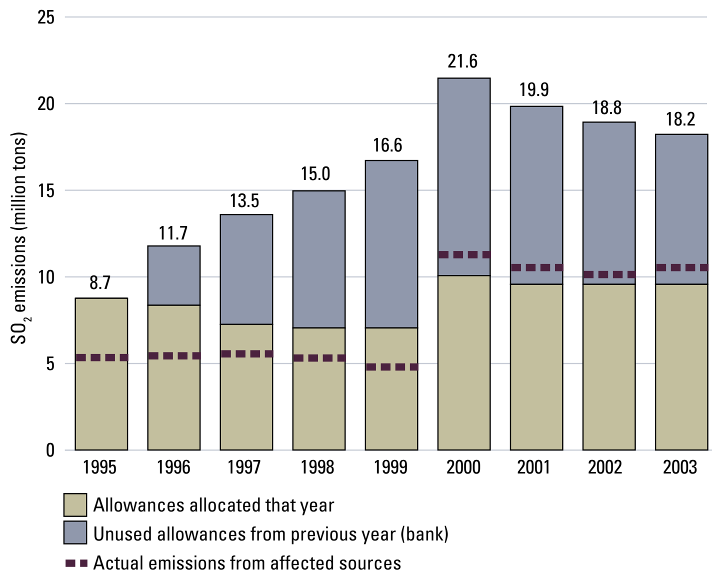


[1] National Emission Inventory 2002: www.epa.gov/ttn/chief/trends/index.html. Emissions from each individual electricity generating unit affected by the Acid Rain Program are available on EPA's Clean Air Markets website at www.epa.gov/airmarkets.

FIGURE 2

SO_2 Emissions and the Allowance Bank, 1995–2003

Source: EPA



As shown in Figure 2, the bank was reduced by 1.1 million allowances (12 percent) in 2003. Over time the bank is expected to continue to be depleted as sources use banked allowances to continue to comply with the stringent Phase II requirements. Figure 3 explains in more detail the origin of the allowances that were available for use in 2003.

In 2010, the annual total of allowances allocated drops to 8.95 million (representing close to 50 percent of the emissions from the power industry in 1980) and remains statutorily fixed at that annual level permanently.

Reductions in SO_2 emissions from other sources not affected by the Acid Rain Program, including smelters and sulfuric acid manufacturing plants, and use of cleaner fuels in residential and commercial burners, have also contributed to the 41 percent decline of SO_2 emissions from all sources since 1980 (National Emission Inventory www.epa.gov/ttn/chief/ trends/index.html).

FIGURE 3

Origin of 2003 Allowable SO_2 Emissions Levels

Source: EPA

Type of Allowance Allocation	Number of Allowances	Explanation of Allowance Allocation Type
Initial Allocation	9,191,897	Initial Allocation is the number of allowances granted to units[1] based on the product of their historic utilization and emissions rates specified in the Clean Air Act.
Allowance Auctions	250,000	Allowance Auctions provide allowances to the market that were set aside in a Special Allowance Reserve when the initial allowance allocation was made.
Opt-in Allowances	99,188	Opt-in Allowances are provided to units entering the program voluntarily. There were 11 opt-in units in 2003.
Total 2003 Allocation	**9,541,085**	
Banked Allowances	8,646,818	Banked Allowances are those held over from 1995 through 2002, which can be used for compliance in 2003 or any future year.
Total 2003 Allowable	**18,187,903**	

[1] In this report, the term "unit" means a fossil-fuel fired combustor that serves a generator that provides electricity for sale. The vast majority of SO_2 emissions affected by the program come from coal-fired generation units, but oil and natural gas units are also included in the program.

The states with the highest emissions in 1990 achieved the greatest SO_2 reductions during the Acid Rain Program. Most of these states were upwind of the areas the Acid Rain Program was designed to protect, and reductions resulted in important environmental and health benefits over a large regional scale (see Figure 4). In addition, the states that reduced emissions had total annual reductions of approximately 5.5 million tons, while the states that had increased emissions — largely attributable to growth and not increases in emissions rates — had much smaller annual increases (a total increase of approximately 440,000 tons).

For 31 states and the District of Columbia, average annual SO_2 emissions in 2000–2003 were lower than annual emissions in 1990. Among these states, twelve states decreased their annual average emissions by more than 100,000 tons between 1990 and 2000–2003. These states were Florida, Georgia, Illinois, Indiana, Kentucky, Massachusetts, Missouri, New York, Ohio, Pennsylvania, Tennessee, and West Virginia. The states with the greatest reductions were in the Midwest and included Ohio (1 million tons of reduction) and Illinois, Indiana, and Missouri (over 500,000 tons of reduction each).

In 17 states annual emissions increased between 1990 and 2000–2003. These states were Arkansas, Colorado, Idaho, Kansas, Louisiana, Minnesota, Montana, Nebraska, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, Texas, Vermont, Virginia, and Wyoming. Only one state increased more than 100,000 tons annually. Of the remaining states, one-third had emissions increases of less than 1,500 tons, another third had increases between 1,500 tons and 20,000 tons, and the remaining third had increases between 20,000 and 100,000 tons.

FIGURE 4

State by State SO_2 Emissions Levels

Source: EPA

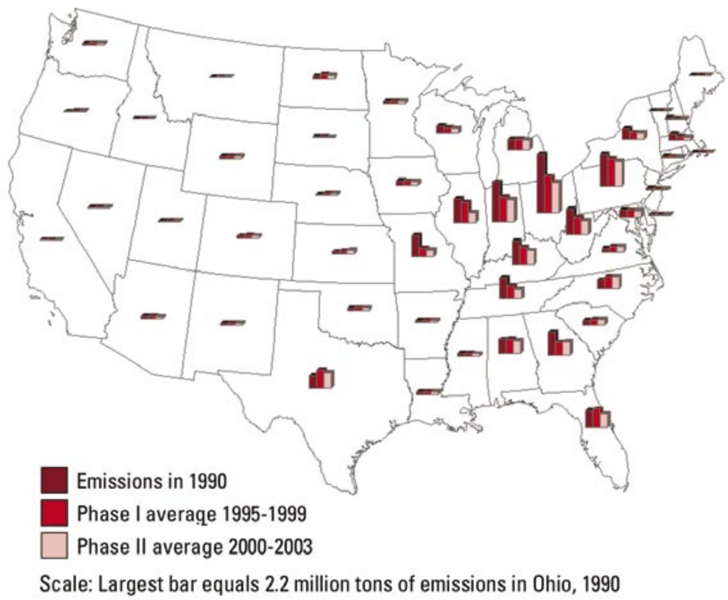
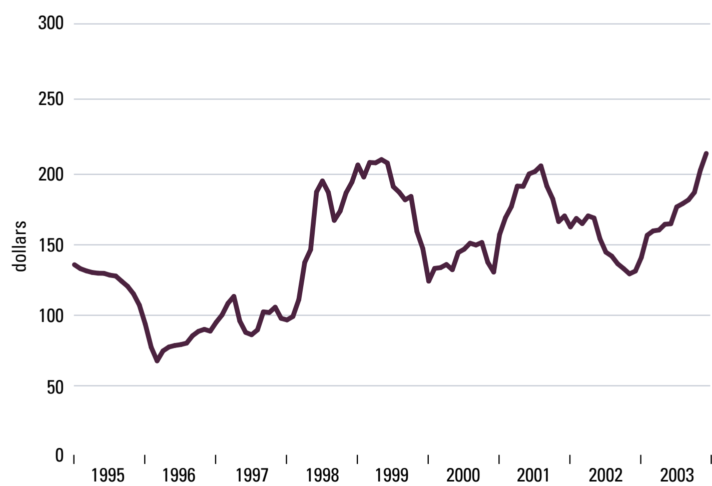


FIGURE 5

SO_2 Allowance Price Index

Source: Cantor Fitzgerald



SO_2 Allowance Market

The allowance trading mechanism of the Acid Rain Program enabled the 3,497 units subject to the SO_2 requirements in 2003 to pursue a variety of compliance options. The allowance market has given some sources the incentive to reduce their SO_2 emissions below the level of their allowance allocation in order to bank their allowances for use in future years or to sell them to other sources. Other sources have been able to postpone or reduce expenditures for control by purchasing allowances from sources that controlled below their allowance allocation level.

Why were SO_2 emissions higher in 2003 than in 2002?

In 2003, electricity sales rose by more than 1 percent. Additionally, relative prices changed among fossil fuels that supply over 70 percent of the nation's power. While coal prices for power generation rose about 1 percent, petroleum prices increased 34 percent, and natural gas prices increased 55 percent. There was hotter-than-normal summer weather in major parts of the country during 2003 and nuclear units were not able to run as hard as they did in 2002. All of this led to coal-fired electricity generation increases of about 2 percent, oil-fired generation increases of 25 percent, and natural gas-fired generation decreases of about 9 percent.[1,2] Coal-fired and oil-fired generation have much higher SO_2 emissions rates than natural gas fired units per unit of electricity output. Close to 75 percent of the additional 400,000 tons of SO_2 emissions emitted from sources in the Acid Rain Program during 2003 come from increased coal-fired generation, and the remainder comes from increased oil-fired generation.[3]

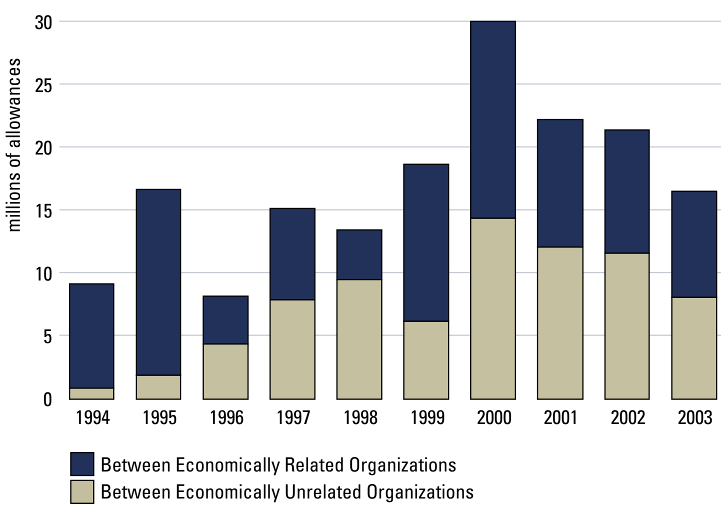
The early, large reductions in SO_2 that sources in the Acid Rain Program made at the start of the Program in the mid-1990s, resulting in emissions that were well below the emissions cap, enabled them to bank allowances to use in situations like this where prices quickly changed and were not foreseen well in advance by many sources of generation. Notably, the overall average rate of SO_2 emissions for coal-fired units did not change substantially from 2002 to 2003, but the amount of coal burned (on a Btu-basis) was about 3 percent higher.

[1] Energy Information Administration, Electric Power Monthly, December 2003, March 2004.
[2] Energy Information Administration, *U.S. Coal Supply and Demand: 2003 Review,* EIA website under coal publications.
[3] EPA's Acid Rain data base for 2003 air emissions.

FIGURE 6

SO_2 Allowances Transferred under the Acid Rain Program

Source: EPA



The marginal cost of compliance — the cost of reducing the next ton of SO_2 emitted from the power sector — is reflected in the price of an allowance.

Allowance prices for 2003 experienced an upward trend, and closed the year roughly 63 percent above the prior year. Prices were in the range of \$150 to \$220 per allowance, ending the year around \$215 (see Figure 5).

In 2003, almost 4,200 allowance transfers affecting roughly 16.5 million allowances (of past, current, and future vintages) were recorded in the EPA Allowance Tracking System. Of the allowances transferred, 8 million (49 percent) were transferred in economically significant transactions (i.e., between economically unrelated parties). The majority of the allowances transferred in economically significant transactions were acquired by power companies. Figure 6 shows the annual volume of SO_2 allowances transferred under the Acid Rain Program since official recording of transfers began in 1994.

Figure 7 shows the cumulative volume of SO_2 allowances transferred under the Acid Rain Program. Over 250 million allowances have been transferred since 1994, with 70 percent of those transfers submitted by authorized account representatives for private accounts. In December 2001, parties began to use a system developed by EPA to allow transfers to occur online. In 2003, 3,536 out of 4,192, or 84 percent, of transfers were done electronically.[2]

[2] All official allowance transactions are posted and updated daily on www.epa.gov/airmarkets.

SO_2 Program Compliance

As in previous years, compliance with the Acid Rain Program continues to be extraordinarily high — nearly 100 percent.

In 2003, one unit out of 3,497 was out of compliance because of 14 tons of excess emissions above the allowances it held. The owner was assessed a penalty of approximately $40,000.

A total of 10.6 million allowances was deducted from sources' accounts in 2003 to cover emissions. Figure 8 displays these allowance deductions, as well as the remaining banked allowances from 1995–2003.

A source that does not hold enough allowances in its unit account to cover its annual SO_2 emissions has "excess emissions" and must pay a $2,900 per ton automatic penalty. Title IV set a penalty of $2,000 in 1990, which has been adjusted annually for inflation, so the year 2003 penalty was $2,900 per ton.

NO_X Emissions Reductions

Title IV of the 1990 Clean Air Act amendments requires NO_X emissions reductions for certain coal-fired units. This portion of the Acid Rain Program applies rate-based NO_X emissions limits to these units and seeks to attain a 2 million ton annual reduction from all power industry sources relative to the NO_X emissions levels projected to occur in 2000 (8.1 million tons) absent the Acid Rain Program. This goal was first realized in 2000, and has been met every year thereafter, including 2003.

Total NO_X mass emissions for coal-fired electric generating units affected by the NO_X program component were reduced to 3.8 million tons from 5.5 million tons in 1990. NO_X emissions from the entire power industry were 4.2 million tons in 2003 (see Figure 9). Reductions from all power generation in 2003 were 2.5 million tons (or 37 percent) below 1990 emissions levels and about half (3.9 million tons) of the forecasted

FIGURE 7

Cumulative SO_2 Allowances Transferred (through 2003)

Source: EPA

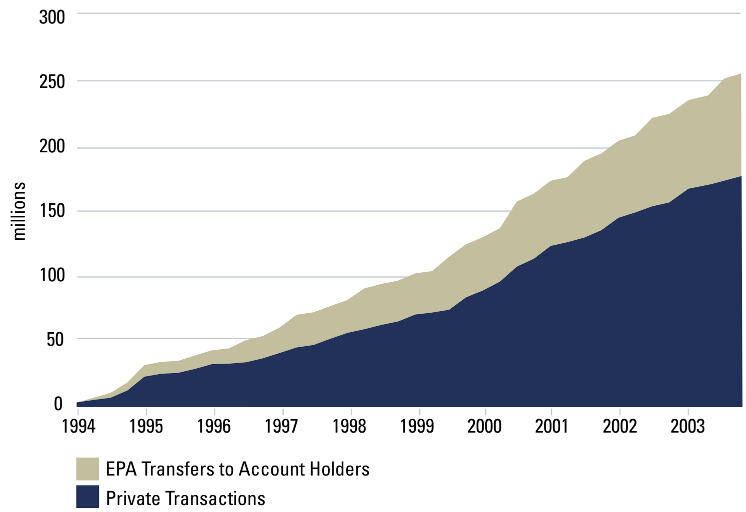


FIGURE 8

SO_2 Allowance Reconciliation Summary, 2003

Source: EPA

Total Allowances Held in Accounts as of 3/1/2004 (1995 through 2003 Vintages)[1]	**18,187,903**
Unit Accounts	14,025,337
General Accounts[2]	4,162,566
Allowances Deducted for Emissions (1995 through 2003)[3]	**10,595,944**
2004 Penalty Allowances Deducted	**14**
Banked Allowances	**7,591,959**
Unit Accounts	3,429,393
General Accounts	4,162,566

[1] The number of allowances held in the Allowance Tracking System (ATS) accounts equals the number of 2003 allowances allocated (see Figure 3) plus the number of banked allowances. March 1, 2004 represents the Allowance Transfer Deadline, the point in time at which unit accounts are frozen and after which no transfers of 1995 through 2003 allowances will be recorded. The freeze on these accounts is removed when annual reconciliation is complete.

[2] General accounts can be established in the ATS by any utility, individual or other organization.

[3] Includes 1,383 allowances deducted from opt-in sources for reduced utilization.

FIGURE 9

NO_X Emissions under the Acid Rain Program

Source: EPA

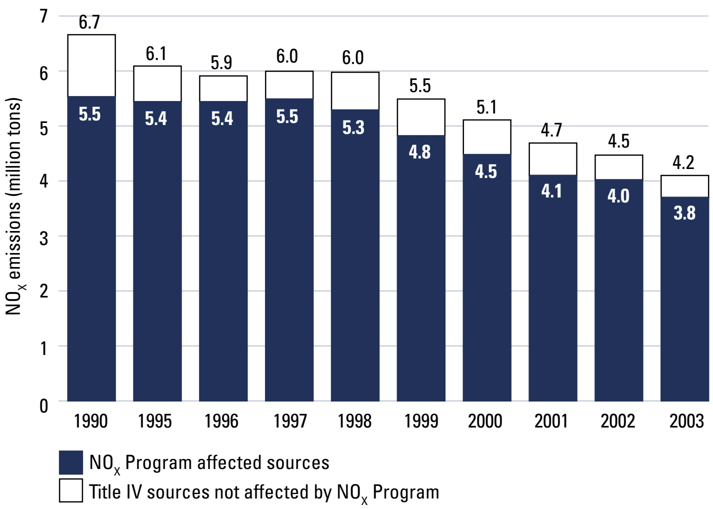
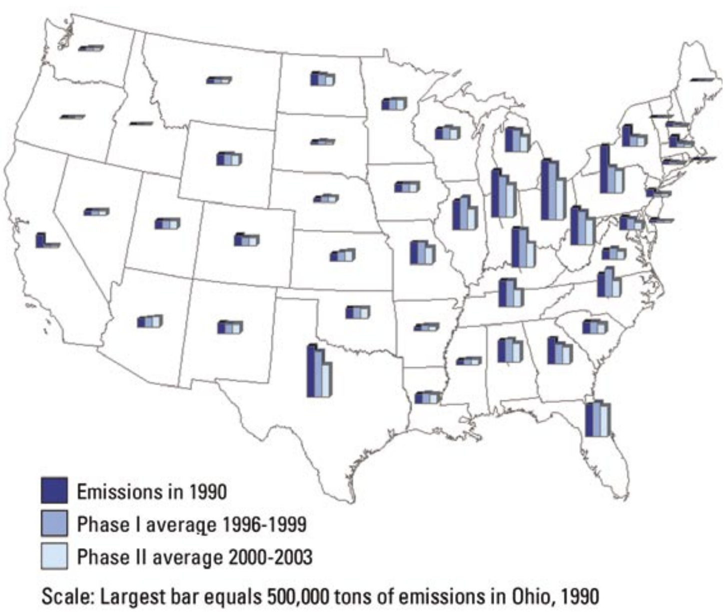


FIGURE 10

State by State NO_X Emissions Levels

Source: EPA



NO_X Compliance Plan Options

Standard Limitation. A unit with a standard limit meets the applicable individual NO_X limit prescribed for its boiler type under 40 CFR 76.5, 76.6, or 76.7.

Early Election. Phase II Group 1 NO_X affected units could meet a less stringent Phase I NO_X limit beginning in 1997, three years before they would normally be subject to an Acid Rain NO_X limit. In return for accepting a NO_X limit three years earlier than would normally be required, an early election unit does not become subject to the more stringent Phase II NO_X limit until 2008.

Emissions Averaging. Many companies have their units meet their NO_X emissions reduction requirements by choosing to become subject to a group NO_X limit, rather than meeting individual NO_X limits for each unit. The group limit is established at the end of each calendar year, and the group rate for the units must be less than or equal to the Btu-weighted group rate units would have had if each had emitted at their standard limit rate.

Alternative Emission Limitation (AEL). A utility can petition for a less stringent AEL if it properly installs and operates the NO_X emissions reduction technology prescribed for that boiler, but is unable to meet its standard limit. EPA determines whether an AEL is warranted based on analyses of emissions data and information about the NO_X control equipment.

levels for 2000. These reductions have been achieved while the amount of fuel burned to produce electricity, as measured by heat input, has increased 30 percent since 1990. Without further reductions in emission rates or the institution of a cap on NO_X emissions, however, NO_X emissions from power plants may rise with increased use of fossil fuels in some areas of the country.

As with SO_2, the states with the highest NO_X emissions in 1990 tended to achieve the greatest emission reductions (see Figure 10). The Acid Rain Program was responsible for a large portion of the annual NO_X reductions, but other programs that control NO_X, such as the OTC NO_X Budget Program, the NO_X SIP call's NO_X Budget Trading Program, and state programs have also contributed to NO_X reductions, particularly in the Northeast. Overall, the states that reduced NO_X emissions from all sources had total annual average reductions of approximately 1.9 million tons for the years 2000–2003, while the states that increased NO_X emissions had much smaller increases (a total increase of approximately 79,000 tons).

For 36 states and the District of Columbia, average annual NO_X emissions from 2000 to

NO_X Emissions

NO_X emissions come from a wide variety of sources including those affected by the Acid Rain Program. NO_X emissions from electric power generation account for approximately 22 percent of NO_X emissions from all sources. NO_X emissions from transportation sources are 55 percent of all NO_X emissions. Nationally, total NO_X emissions have decreased 12 percent from 1990 through 2001. NO_X emissions from transportation sources decreased 14 percent, but NO_X emissions from heavy duty vehicles increased by 10 percent. The emission decreases from electric power generation and other fuel combustion sources are due in part to a variety of federal and state emission reduction programs (including the Acid Rain Program, the Ozone Transport Commission NO_X Budget Program, and the NO_X SIP call) and federal enforcement actions (National Emissions Inventory www.epa.gov/ttn/chief/trends/index.html).

2003 were lower than annual NO_X emissions in 1990. The states with the greatest reductions included Pennsylvania (more than 200,000 tons of reductions) and Indiana, Kentucky, New York, Ohio, Texas, and West Virginia (with more than 100,000 tons of reductions each).

Twelve states had average annual emissions from 2000–2003 that were greater than annual 1990 NO_X emissions: Arizona, Arkansas, Idaho, Kansas, Minnesota, Mississippi, Montana, Nebraska, Oregon, Utah, Vermont, and Washington. One-third of the states had increases well under 2,000 tons. Another third had increases between 2,000 tons and 6,500 tons, and the remaining states had increases between 6,500 tons and 22,000 tons.

NO_X Emissions Limits

Instead of using cap and trade to achieve NO_X emissions reductions, the Acid Rain Program establishes NO_X emissions limitations (lb/mmBtu) for the boilers of most coal-fired electric generation units. The Acid Rain Program NO_X regulation (40 CFR part 76) establishes emissions limits for each boiler type (see Figure 11). Unit operators have several options for complying with the limits (see text box on NO_X Compliance Plan Options).

FIGURE 11

Number of NO_X Affected Units by Boiler Type

Source: EPA

Coal-Fired Boiler Type	Standard Emission Limit (lb/mmBtu)	Number of Units
Phase I Group 1 Tangentially-fired	0.45	132
Phase I Group 1 Dry Bottom Wall-fired	0.50	119
Phase II Group 1 Tangentially-fired	0.40	302
Phase II Group 1 Dry Bottom Wall-fired	0.46	306
Cell Burners	0.68	37
Cyclones > 155 MW	0.86	56
Wet Bottom > 65 MW	0.84	26
Vertically-fired	0.80	26
Total		**1,004**

FIGURE 12

Compliance Options in the NO_X Program, 2003

Source: EPA

Compliance Option	Units covered by Compliance Option
Standard Emission Limitation	121
Early Election	271
Emissions Averaging	623
Alternative Emission Limitation	25
Total	**1,040***

*The total number of units covered by specific NO_X compliance options is greater than 1,004 because some units have multiple compliance plans. For calendar year 2003, 28 units had both early election and averaging plans, and 8 units had both AEL and emissions averaging compliance plans (1,004 plus 28 plus 8 equals 1,040).

NO_X Program Compliance

In 2003, 1,049 Acid Rain Program units were required to meet NO_X emission limitations. Of these 1,049 coal-fired units, 45 have been retired,

Continuous Emissions Monitoring Systems (CEMS)

Electricity generating units under the Acid Rain Program are required to measure and record emissions using Continuous Emissions Monitoring Systems (CEMS) or an approved alternative measurement method. Since the program's inception in 1995, the emissions data — continuously reported by sources, verified and recorded by EPA, and posted for public consumption on the Internet — have been among the most complete and accurate data ever collected by EPA. Electronic audit capabilities include software that performs rigorous checks to ensure the completeness, high quality, and integrity of the emissions data. In 2003, for the third consecutive year, 100 percent of affected sources were reporting hourly emissions electronically. CEMS are a cornerstone of the program's accountability and transparency.

leaving 1,004 NO_X units that must meet their NO_X emissions limits through compliance with their respective NO_X compliance plans.[3] Figure 12 summarizes the compliance options chosen for NO_X affected units in 2003. Emissions averaging was the most widely chosen compliance option; 57 emissions averaging plans involving 623 units were employed in 2003. No units were out of compliance with the NO_X program.

Status and Trends in Acid Deposition, Air Quality and Ecological Effects

The emission reductions achieved under the Acid Rain Program have led to important environmental and public health benefits. These include improvements in air quality with significant benefits to human health, reductions in acid deposition, the beginnings of recovery from acidification of fresh water lakes and streams, improvements in visibility, and reduced risk to forests, materials and structures.

To evaluate the impact of emissions reductions on the environment, scientists and policymakers use data collected from long-term national monitoring networks such as the Clean Air Status and Trends Network (CASTNET) and the National Atmospheric Deposition Program (NADP).

Data collected from monitoring networks show that the decline in SO_2 emissions from the power industry has decreased acidic deposition and improved air quality. The decline in NO_X emissions, however, has not been as significant and the environmental improvements are not as wide-

Deposition Monitoring Networks

To evaluate the impact of emissions reductions on the environment, scientists and policymakers use data collected from long-term national monitoring networks such as the Clean Air Status and Trends Network (CASTNET) and the National Atmospheric Deposition Program (NADP). Deposition and air quality monitoring data from these and other air quality monitoring networks can be accessed on or through the CASTNET website at www.epa.gov/castnet. CASTNET provides atmospheric data on the dry deposition component of total acid deposition, ground-level ozone, and other forms of atmospheric pollution. CASTNET is considered the nation's primary source for atmospheric data to estimate dry acidic deposition and to provide data on rural ozone levels. Used in conjunction with other national monitoring networks, CASTNET data are used to determine the effectiveness of national emission control programs. Established in 1987, CASTNET now comprises over 70 monitoring stations across the U.S. The longest data records are primarily at eastern sites. EPA operates a majority of the monitoring stations; however, the National Park Service operates approximately 30 stations in cooperation with EPA.

CASTNET continues to provide accountability and performance measure-related information for the Acid Rain Program and is available to provide deposition and air quality baselines to support future accountability and program evaluation needs. As such, both near and long-term program goals involve advancing the monitoring and assessment capabilities of the network to better inform transport and air quality model evaluation. Future changes will also provide critical information for implementation of an integrated monitoring strategy for the U.S. and Canada.

[3] Detailed compliance information by unit can be found on EPA's Clean Air Markets website at www.epa.gov/airmarkets.

spread. Although the Acid Rain Program has met its NO_X reduction targets, total nitrogen deposition has increased in many areas of the country due to other sources such as motor vehicles and agriculture.

Acid Deposition

During the late 1990s, following implementation of Phase I of the Acid Rain Program, dramatic regional improvements in SO_2 and ambient sulfate concentrations were observed at CASTNET sites throughout the Eastern U.S. This is due to the large reductions in SO_2 emissions from Acid Rain sources. Analyses of regional monitoring data from CASTNET show the geographic pattern of SO_2 and airborne sulfate in the Eastern U.S. Three-year mean, annual concentrations of SO_2 and sulfate from CASTNET long-term monitoring sites are compared from 1989 through 1991 and 2001 through 2003 in both tabular results and graphically (see Figures 13-18).[4,5]

From 1989 through 1991, prior to implementation of Phase I of Title IV, the highest ambient concentrations of SO_2 in the East were observed in Western Pennsylvania and along the Ohio River Valley. Ambient SO_2 concentrations have decreased significantly since 1991, with average concentrations in the Eastern U.S. decreasing 57 percent in the Northeast and 38 percent in the Mid-Atlantic region (see Figures 13, 14a and 14b).

Before the program, in 1989 through 1991 (see Figures 15a-15b), the highest ambient sulfate concentrations, greater than 7 $\mu g/m^3$, were observed in Western Pennsylvania, along the Ohio River Valley, and in Northern Alabama. Most of the Eastern U.S. experienced annual ambient sulfate concentrations greater than 5 $\mu g/m^3$.

Like SO_2 concentrations, ambient sulfate concentrations have decreased since the program was implemented, with average concentrations decreasing approximately 30 percent in all regions of the Eastern U.S. Both the size of the affected region and magnitude of the highest con-

FIGURE 13

Regional Changes in Deposition of Sulfur and Nitrogen from 1989-91 to 2001-03

Source: EPA

Measurement	Unit	Region	Average 1989-91	Average 2001-03	Percent Change
Wet sulfate deposition	kg/ha	Mid-Atlantic	28	20	-29
		Midwest	25	16	-36
		Northeast	23	14	-39
		Southeast	18	15	-17
Wet sulfate concentration	mg/L	Mid-Atlantic	2.3	1.7	-26
		Midwest	2.2	1.6	-27
		Northeast	1.8	1.3	-28
		Southeast	1.4	1.1	-21
Ambient sulfur dioxide concentration	ug/m^3	Mid-Atlantic	13	8	-38
		Midwest	11	6	-45
		Northeast	7	3	-57
		Southeast	5	3	-40
Ambient sulfate concentration	ug/m^3	Mid-Atlantic	6.4	4.7	-27
		Midwest	5.6	3.9	-30
		Northeast	3.9	2.7	-31
		Southeast	5.6	3.9	-30
Wet inorganic nitrogen deposition	kg/ha	Mid-Atlantic	5.9	5.3	-10
		Midwest	6.0	5.8	-3
		Northeast	5.3	4.4	-17
		Southeast	4.3	4.2	-2
Wet nitrate concentration	mg/L	Mid-Atlantic	1.4	1.2	-14
		Midwest	1.4	1.4	0
		Northeast	1.3	1.1	-15
		Southeast	0.8	0.8	0
Total ambient nitrate concentration	ug/m^3	Mid-Atlantic	3.5	3.0	-14
		Midwest	4.0	3.8	-5
		Northeast	2.0	2.0	0
		Southeast	2.2	2.1	-5

Based on data compiled annually by the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) nadp.sws.uiuc.edu and the Clean Air Status and Trends Network (CASTNET) www.epa.gov/castnet.

4 Points on maps represent location of monitoring sites.

5 Based on data compiled annually by the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) nadp.sws.uiuc.edu and the Clean Air Status and Trends Network (CASTNET) www.epa.gov/castnet.

FIGURE 14a

Annual Mean Ambient Sulfur Dioxide Concentration 1989 through 1991

Source: CASTNET

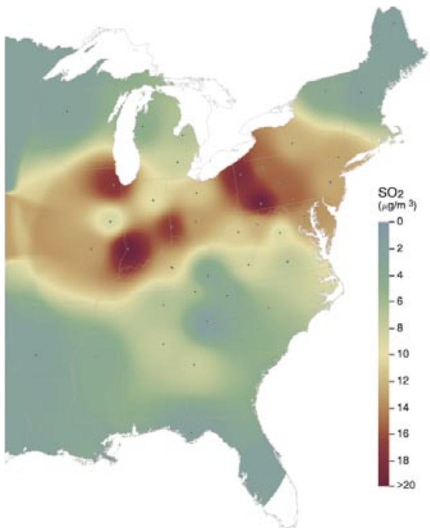
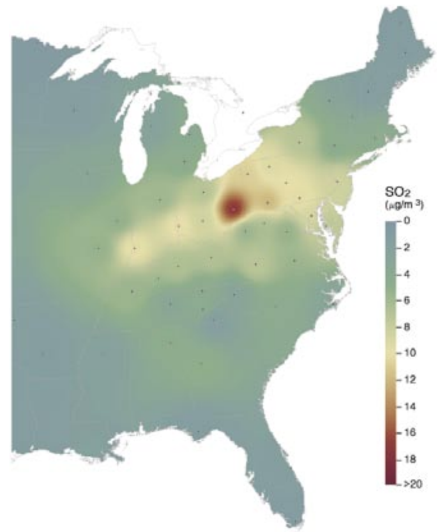


FIGURE 14b

Annual Mean Ambient Sulfur Dioxide Concentration 2001 through 2003

Source: CASTNET



centrations were dramatically reduced following implementation of Title IV. The largest decreases were observed along the Ohio River Valley (see Figures 15a-15b).

Analyses of the NADP long-term monitoring data show that wet sulfate deposition, sulfate that falls to the earth through rain, snow, and fog, has also decreased since the Acid Rain Program was implemented. A strong correlation between large scale SO_2 emissions reductions and large reductions in sulfate concentrations in precipitation has been noted for the Northeast, one of the areas most affected by acid deposition. Some of the greatest reductions in wet sulfate deposition occurred in the Mid-Appalachian region, including Maryland, New York, West Virginia, Virginia, and most of Pennsylvania. Wet sulfate deposition decreased throughout the early 1990s in much of the Ohio River Valley and Northeastern U.S. Other less dramatic reductions were observed across much of New England, portions of the Southern Appalachian Mountains and in the Midwest. Average decreases in wet deposition of sulfate range from 39 percent in the Northeast to 17 percent in the Southeast (see Figures 16a-16b).

A principal reason for reduced concentrations of sulfate in precipitation in the Northeast is a reduction in the long-range transport of sulfate from emission sources located in the Ohio River Valley. The reductions in sulfate documented in the Northeast, particularly across New England and portions of New York, were also affected by SO_2 emissions reductions in Eastern Canada. Concurrent with these sulfate reductions were similar reductions in precipitation acidity, expressed as hydrogen ion (H+) concentrations (NADP).

Sources affected by the Acid Rain Program account for a portion of nationwide NO_X emissions. Emissions trends from other source categories also affect air concentrations and deposition of nitrogen. Significant improvements in nitrogen deposition have not been evident since the Acid Rain Program began.

Inorganic nitrogen deposition and wet nitrate concentrations have decreased modestly since

FIGURE 15a

Annual Mean Ambient Sulfate Concentration 1989 through 1991

Source: CASTNET

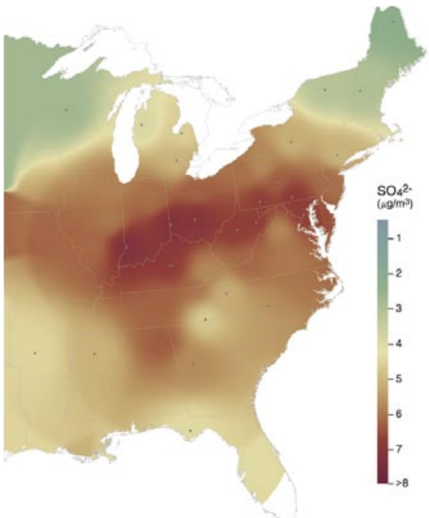


FIGURE 15b

Annual Mean Ambient Sulfate Concentration 2001 through 2003

Source: CASTNET

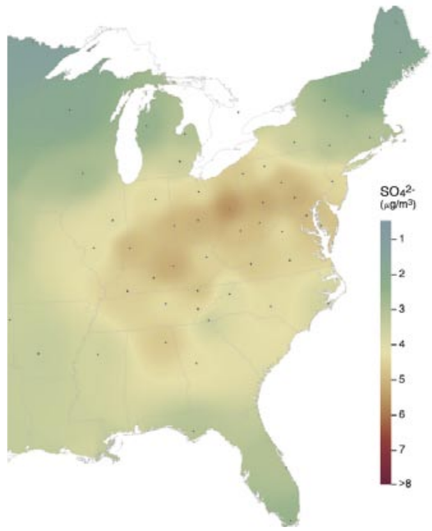


FIGURE 16a

Annual Mean Wet Sulfate Deposition 1989 through 1991

Source: National Atmospheric Deposition Program

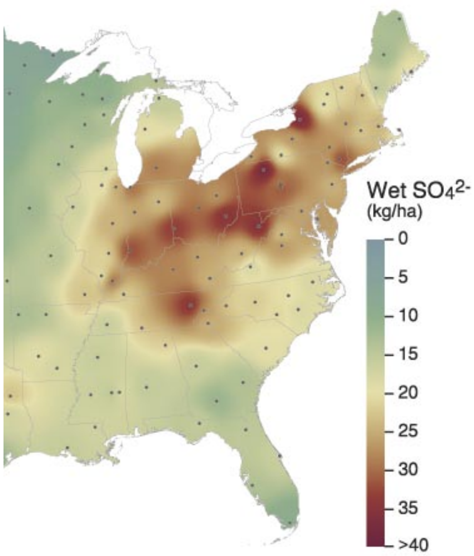


FIGURE 16b

Annual Mean Wet Sulfate Deposition 2001 through 2003

Source: National Atmospheric Deposition Program

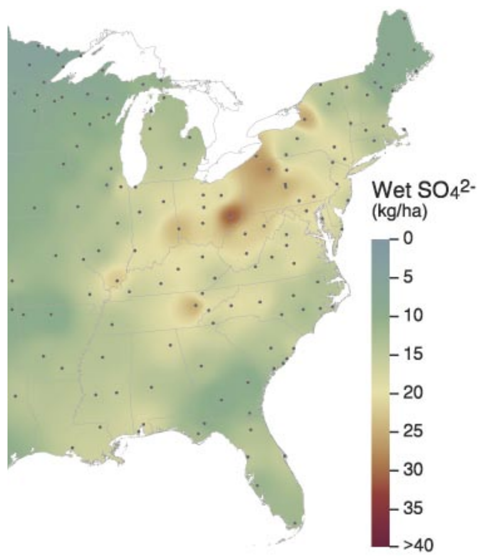


FIGURE 17a

Annual Mean Wet Inorganic Nitrogen Deposition 1989 through 1991

Source: National Atmospheric Deposition Program

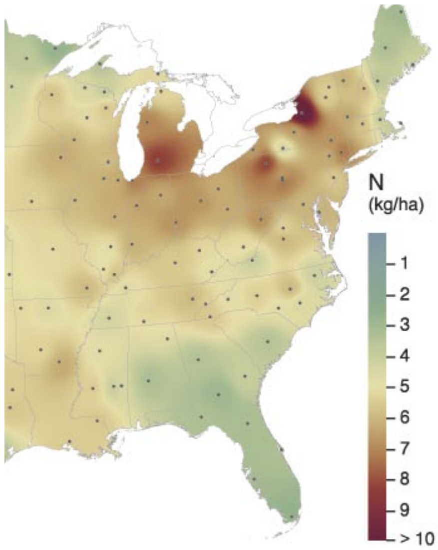


FIGURE 17b

Annual Mean Wet Inorganic Nitrogen Deposition 2001 through 2003

Source: National Atmospheric Deposition Program

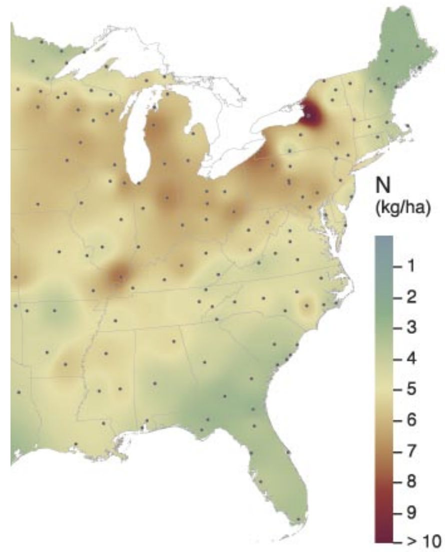


FIGURE 18a

Annual Mean Total Ambient Nitrate Concentration 1989 through 1991

Source: CASTNET

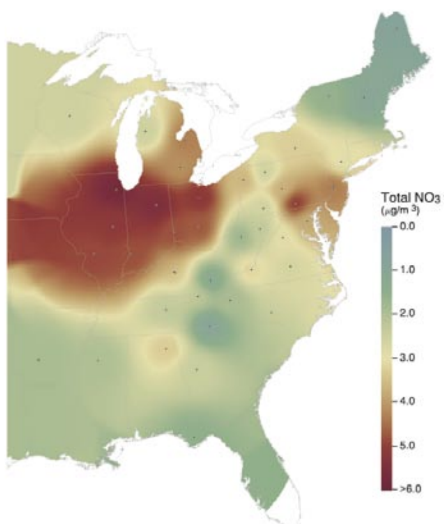
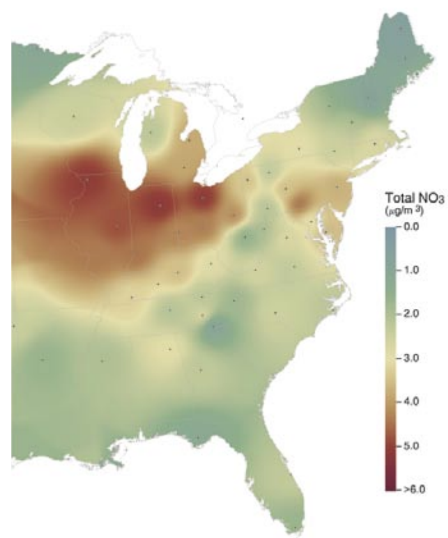


FIGURE 18b

Annual Mean Total Ambient Nitrate Concentration 2001 through 2003

Source: CASTNET



1991 in the Mid-Atlantic and Northeast regions, but have remained relatively constant in the Midwest and Southeast (see Figures 17a-17b).

Ambient nitrate concentrations (nitric acid plus particulate nitrate) have also decreased in the Mid-Atlantic, but have remained relatively constant in other regions of the Eastern U.S. (see Figures 18a-18b).

Recovery of Acidified Lakes and Streams

While climate change, forest maturation, disturbances such as pest outbreaks, and land use history all impact ecosystems that are also affected by acid deposition, scientists have demonstrated measurable improvements in some lakes and streams resulting from the Acid Rain Program.[6] Scientists studied lakes and streams in five regions — New England, the Adirondack Mountains, the Northern Appalachian Plateau (including the Catskill Mountains), the Upper Midwest, and the Ridge/Blue Ridge — and found signs of recovery in many, but not all, of those areas (see Figure 19). These signs of recovery include reductions in sulfate and aluminum concentrations and decreases in acidity.

For example, almost all Adirondack lakes had reductions in sulfate concentrations that coincide with reductions in atmospheric concentrations of sulfur. These reductions in sulfate, as well as reductions in nitrate concentrations that do not appear to be due to changes in atmospheric deposition, have resulted in increased pH and acid neutralizing capacity (ANC is an indicator of aquatic ecosystem recovery) as well as reductions in the amount of toxic inorganic aluminum in Adirondack lakes.

Increasing ANC was evident in three of the regions studied (Adirondacks, Northern Appalachian Plateau, and Upper Midwest). One-quarter to one-third of lakes and streams in these regions previously affected by acid rain are no longer acidic at base-flow conditions, although they are still highly sensitive to future changes in deposition.

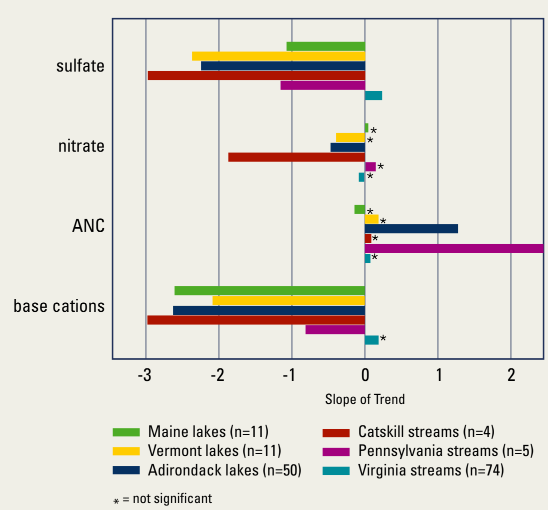
Improvements in Surface Water

Long-term monitoring networks provide information on the chemistry of lakes and streams, which allows us to look at how water bodies are responding to changes in emissions. The data presented here show regional trends in acidification from 1990 to 2000 in areas of the eastern U.S. For each lake or stream in the network, measurements of various indicators of recovery from acidification were taken. These measurements were plotted against time, and trends for the given lake or stream during the ten-year period were then calculated as the change in each of the measurements per year (e.g., change in concentration of sulfate per year). Using the trends calculated for each water body, median regional changes were determined for each of the measures of recovery. A negative value of the "slope of the trend" means that the measure has been declining in the region, while a positive value means it has been increasing. The greater the value of the trend, the greater the yearly change in the measurement. Movement toward recovery is indicated by positive trends in acid neutralizing capacity (ANC) and negative trends in sulfate, nitrate, hydrogen ion, and aluminum. Negative trends in base cations can balance out the decreasing trends in sulfate and nitrate and prevent ANC from increasing.

FIGURE 19

Regional Trends in Lake and Stream Acidification 1990-2000

Source: EPA



Source: Stoddard, J. L., J. S. Kahl, F. A. Deviney, D. R. DeWalle, C. T. Driscoll, A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, J. R. Webb, and K. E. Webster. 2003. *Response of surface water chemistry to the Clean Air Act Amendments of 1990.* EPA/620/R-03/001, U.S. Environmental Protection Agency, Washington, DC.)

[6] Stoddard, J. L., J. S. Kahl, F. A. Deviney, D. R. DeWalle, C. T. Driscoll, A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, J. R. Webb, and K. E. Webster. 2003. *Response of surface water chemistry to the Clean Air Act Amendments of 1990.* EPA/620/R-03/001, U.S. Environmental Protection Agency, Washington, DC.)

Specifically:

- Eight percent of the lakes in the Adirondacks are acidic, down from 13 percent in the early 1990s.
- Fewer than 1 percent of lakes in the Upper Midwest are acidic, down from 3 percent in the early 1980s.
- Eight percent of the streams in the Northern Appalachian Plateau region are currently acidic during base-flow conditions, down from 12 percent in the early 1990s.

In New England and the Ridge/Blue Ridge regions, however, there have been no significant improvements, suggesting that additional reductions are necessary for ecosystem recovery. Specifically:

- In New England, 5.5 percent of lakes are acidic, an insignificant change from the early 1990s when 5.6 percent of lakes in the region were acidic.
- There has been no change in the number of acidic waters in the Ridge/Blue Ridge region in the past decade.

The data on sulfate concentrations are similar to that for ANC; there have been decreases in lake sulfate concentrations in some but not all of the regions studied. Trends in nitrate concentrations were much smaller than trends in sulfate concentrations, though lakes in the Adirondacks and streams in the northern Appalachian Plateau exhibited significant downward trends in nitrate in the 1990s. It should be noted, however, that this does not appear to reflect changes in emissions or deposition in these areas and is likely a result of ecosystem factors that are not yet fully understood.

Long-Term Environmental Monitoring at EPA

EPA's Temporally Integrated Monitoring of Ecosystems (TIME) and Long-Term Monitoring (LTM) programs are designed to detect trends in the chemistry of regional populations of lakes or streams and to determine whether emissions reductions have had the intended effect of reducing acidification. TIME/LTM monitors a total of 145 lakes and 147 streams, representing all of the major acid sensitive regions of the northern and eastern U.S. (upper Midwest, New England, Adirondack Mountains, northern Appalachian Plateau (including the Catskill Mountains), and the Ridge/Blue Ridge Provinces of Virginia). TIME/LTM measures a variety of important chemical characteristics, including ANC, pH, sulfate, nitrate, major cations (e.g., calcium and magnesium), and aluminum. While the representativeness of the TIME/LTM network is somewhat limited, the TIME program is the most coherent individual regional dataset for this kind of analysis. In addition, the U.S. Geological Survey has been measuring surface water quality at several research watersheds throughout the U.S., where sample collection during hydrologic events and ancillary data on other watershed characteristics have been used to assess the watershed processes controlling acidification of surface waters.

Quantifying Costs and Benefits of the Acid Rain Program

Later estimates of the cost of full implementation of the Acid Rain trading program for SO_2 are significantly lower than originally estimated. Independent analyses have estimated annual costs in the range of $1 to $2 billion per year (2000$) in 2010 when the program is nearly fully implemented, substantially less than were predicted in 1990. The most recent estimates provided by Ellerman and by Carlson are $1.3 to $1.5 billion/year ($2000) and $1.1 billion/year by 2010, respectively[7,8]. A recent Office of Management and Budget (OMB) analysis estimated costs of the SO_2 program between $1.1 and $1.8 billion[9]. EPA expects NO_X costs to be no more than a billion

[7] Ellerman, Denny, "Lessons from Phase 2 Compliance with the U.S. Acid Rain Program," MIT Center for Energy and Environmental Policy Research, Cambridge, MA, 2003.

[8] Carlson, Curtis P., Dallas Burtraw, Maureen Cropper, and Karen Palmer (Carlson et al, 2000). "SO_2 Control by Electric Utilities: What are the Gains from Trade?" Journal of Political Economy, Vol. 108, No. 6: 1292-1326.

[9] Informing Regulatory Decisions: 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities, 2003 Office of Management and Budget, Office of Information and Regulatory Affairs www.whitehouse.gov/omb/inforeg/2003_cost-ben_final_rpt.pdf.

dollars annually, and likely to be substantially less from the limited analysis that has been done in this area.

The OMB study also found that the Acid Rain Program accounted for the largest quantified annual human health benefits — over $70 billion — of any federal regulatory program implemented in the last 10 years, with annual benefits exceeding costs by more than 40:1.

The benefits to New Yorkers of improving natural resources in the Adirondacks are estimated to be between $300 million and $750 million per year, according to a new study by Resources for the Future (RFF). The five-year study, supported by an EPA grant, estimates New Yorkers' willingness-to-pay for total ecological benefits in the Adirondack Park at $38 to $113 per household per year. (This total benefit estimate is the sum of use and nonuse benefits — benefits to New Yorkers who use the Park as well as to those NY residents who do not visit the Park but want to know this resource is being protected.) The Acid Rain Program, Title IV of the 1990 Clean Air Act Amendments, was passed in part, in response to the public's concern about the acidification of lakes and soils in the Adirondacks. By reducing NO_X and SO_2 emissions from power plants, acidic deposition in lakes and on shallow soils with low acid neutralizing capacity is also reduced. Until now, policy makers had no way of considering the total economic value of such environmental improvements. RFF's rigorous methodology involved extensive use of focus groups and a carefully crafted survey of a representative sample of over 1,800 New Yorkers administered on the internet and by mail. The project, while specific to the Adirondack Park, nevertheless suggests benefits can be estimated using a similar methodology for other ecological resource improvements that result from improvements in air quality.

National Tools for Further Emission Reductions

The Acid Rain Program has proven to be an effective and efficient means of reducing SO_2 and NO_X emissions from power plants. However, it is increasingly clear that further reductions are needed not only to continue reductions in acid rain, but also to reduce ground level ozone, regional haze, and fine particles. To achieve these important reductions, the EPA has developed the Clean Air Rules, a suite of actions that will dramatically improve air quality nationwide. Three of the rules — the Clean Air Interstate Rule, Clean Air Mercury Rule, and Clean Air Nonroad Rule — specifically address the transport of pollution across state borders. They provide much needed, national regulatory controls, like the Acid Rain Program, to achieve significant improvements in air quality, health, and quality of life. The proposed Clean Air Mercury and Clean Air Interstate Rules, which may use the cap and trade approach to achieve required reductions, create a multi-pollutant strategy to reduce power plant emissions of SO_2, NO_X, and mercury. Taken together, this suite of rules in conjunction with state and regional programs, will build on past successes and make the next 15 years one of the most productive periods of air quality improvement in our history.

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